Smart Habitat:
Identifying Technological Countermeasures to Address Health and Performance Risks during Long-Duration Exploration Missions

Ryan A. Lange[1] , Patrick K. Pischulti[1] , Amanda L. Smith[2] , Giovanna Camacho[3] , Tyler L. Duke[4] , and Ryan Z. Amick[2]

[1]GeoLogics, [2]KBR, [3]Embry-Riddle Aeronautical University, [4]Leidos

Background

During proposed long-duration Exploration Missions, crews must become increasingly autonomous, as they will be unable to rely on consistent input and guidance from ground-based mission control operations.

Problem Statement

While it is known that smart technologies will play a crucial role in future long-duration Exploration Missions, it is not known which manner of devices and systems may best mitigate the expected risks to crew.

The purpose of this project was to identify both current and emerging technologies which may act as health and performance countermeasures on long-duration Exploration Missions.

Project Goals

(1) Identify consumer, industrial, future, or other smart technologies which may contribute to the mitigation of health and performance risks on missions with increased crew autonomy.

(2) Identify future research opportunities for the applications of smart technologies in spacecraft.

(3) Refine the conceptual definition of a Smart Habitat.

Definitions

XR
Extended Reality

All real and virtual environments and their respective interactions

VR
Virtual Reality

Fully immersive, virtual environment

AR
Augmented Reality

Real-world scene combined with virtual elements

Internet of Everything (IOE)
The intelligent connections between people, process, data, and things with the goal of turning information into actions.

Internet of Things (IOT)
A network of physical electronic devices that collect and exchange data without human intervention to form an ecosystem of connected objects.

XR Literature Review

A literature review was conducted with a focus on the applications of Extended Reality (XR) devices in isolated, confined, and extreme environments. This included Virtual Reality and Augmented Reality (VR, AR) devices and applications.

7 key health and performance related applications for these technologies were identified:

Mitigation of Stress
XR devices may be used for meditation and other stress-relief related activities.

Sensory Stimulation
Programs may be used to augment sensory cues in the spacecraft environment.


Image credit: NASA

Health Maintenance
Imagery and animations can be easily displayed on real-world scenes with XR technology, assisting crew to complete medical procedures without the need for ground-based assistance.

Facilitation of Social Interaction
XR devices may be used to communicate with friends and family on Earth or facilitate social activities onboard the spacecraft.

Exercise
XR programs for advanced exercise routines add both complexity and enjoyment to workouts.


Image credit: ESA

Awe
Beautiful beaches, stunning mountain ranges, and other wonderous virtual environments may improve moods of crewmembers and reduce homesickness.

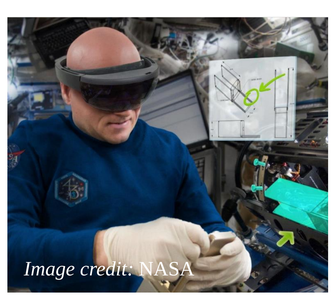
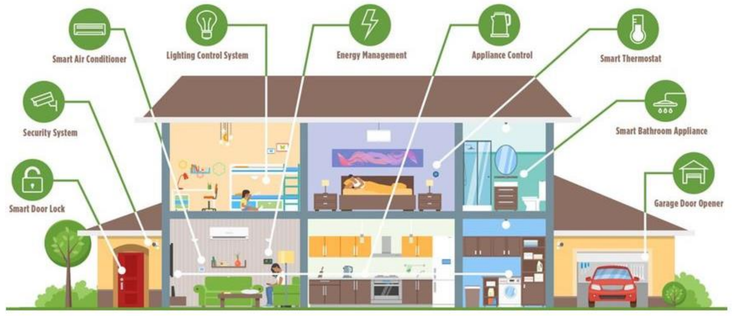


Image credit: NASA

Task Training and Communication Support
Training for future, complex mission procedures will be possible during long cruise phases, reducing the need for pre-flight training time on the ground. Crew may also use XR technologies to facilitate intra and inter-vehicular communications throughout the mission.

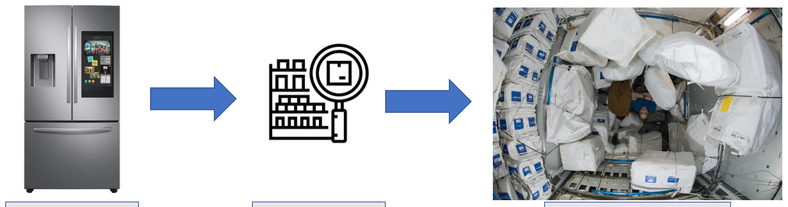
COTS Trade Study

A trade study was conducted to identify commercial off-the-shelf (COTS) technologies that may serve as readily available health and performance countermeasures.



87 products were identified as “smart” devices widely available to consumers.

Individual product features for each device were then decomposed by function and assigned to potential habitat functional areas. For example: a smart refrigerator might be able to identify its contents and update a user’s shopping list. This is an inventory feature which may be used to track spacecraft supplies in a storage location.



This decomposition of the product functions enabled understanding of their potential applications to spacecraft environments and their potential for mitigation of crew health and performance risks.

Discussion and Forward Work

Through the lens of automation research, future studies should focus on the following:

(1) Investigating the potential applications of XR devices in long-duration spacecraft

(2) Expanding the definition of what is considered a smart device
- Numerous consumer products only perform simple task augmentation yet still receive “smart” branding, which is typically indicative of greater automation.
- Many of these products act as internet of things (IoT) devices, where the desired characteristics for spacecraft implementation align more closely with the internet of everything (IoE) definition